Possible Radiation Damage to Permanent Magnets in the LCLS

S. Milton 1 Oct. 03 MAP
What’s this about?

- A $50M -> $55M Undulator System for the LCLS
- Beam losses can damage this...
- ...and I’m responsible for seeing that this does not occur...
- ...but I do not know how to ensure this yet!
What do I want out of this?

• A better understanding of the damage mechanism
• What are the thresholds for NdFeBo and SmCo
• How can I protect the magnets?
• Some ideas for a good and reliable machine protection system (detectors)
The LCLS
(Linac Coherent Light Source)

Undulator Systems WBS 1.4
Full Length Prototype

Performance Measured to be within the Design Specification
Field Control Concept
Alanine dosimeter readings (Mrad)
U27#12 Damage Sequence

Peak Field [gauss]

Pole #

- May-97
- Apr-03
- Dec-01
Damage Distribution in Magnet Block

Magnet #6 from U/S end of APS#2 Undulator
Should I be Worried?

- Scaling from the APS Experience and that of the TTF at DESY
  - I need to keep damage down to less than 1 part in 10,000
  - This means losses on the order of from 10 nC to 100 nC could damage an undulator

- LCLS Parameters
  - 1 nC/pulse at up to 120 Hz
  - Damage can occur very quickly!!
  - Even 1 part in $10^6$ losses over roughly 100 hours can be a serious issue!!
Demagnetization of undulator magnets irradiated high energy electrons

T. Bizen\textsuperscript{a,\ast}, T. Tanaka\textsuperscript{b}, Y. Asano\textsuperscript{c}, D.E. Kim\textsuperscript{d}, J.S. Bak\textsuperscript{d}, H.S. Lee\textsuperscript{d}, H. Kitamura\textsuperscript{b}

\textsuperscript{a}SPRING\-8/JASRI, 1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5198, Japan
\textsuperscript{b}SPRING\-8/RIKEN, 1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5198, Japan
\textsuperscript{c}SPRING\-8/JAERI, 1-1-1 Kouto, Mikazuki-cho, Sayo-gun, Hyogo 679-5198, Japan
\textsuperscript{d}Pohang Accelerator Laboratory, POSTECH, San31, Hojea-dong, Pohang 790-784, South Korea

Abstract

The magnetic field change of undulator magnets when exposed to a 2.0 GeV electron beam has been measured. We study the effect of (1) stacking magnets, of (2) magnet shape, of (3) magnetized direction, of (4) target materials, of (5) magnet materials, and of (6) manufacturers. Two undulator models adopting the actual magnet array dimensions of the in-vacuum undulators in SPRing-8 were also irradiated. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Demagnetization; Magnetic field; Nd–Fe–B magnet; Undulator; Electron beam; Radiation
Table 1
Magnet sample list\textsuperscript{a}

<table>
<thead>
<tr>
<th>Label</th>
<th>Material code</th>
<th>( B_r ) (T)\textsuperscript{b}</th>
<th>( H_{cj} ) (kA/m)\textsuperscript{b}</th>
<th>Manufacturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>V411</td>
<td>VACODYM411</td>
<td>1.00</td>
<td>3260</td>
<td>VAC</td>
</tr>
<tr>
<td>V400</td>
<td>VACODYM400</td>
<td>1.10</td>
<td>2470</td>
<td>VAC</td>
</tr>
<tr>
<td>V396</td>
<td>VACODYM396</td>
<td>1.15</td>
<td>2150</td>
<td>VAC</td>
</tr>
<tr>
<td>N32</td>
<td>NEOMAX-32EH</td>
<td>1.11</td>
<td>2387</td>
<td>SSMC</td>
</tr>
<tr>
<td>N35</td>
<td>NEOMAX-35EH</td>
<td>1.17</td>
<td>1989</td>
<td>SSMC</td>
</tr>
<tr>
<td>N44</td>
<td>NEOMAX-44H</td>
<td>1.36</td>
<td>1273</td>
<td>SSMC</td>
</tr>
<tr>
<td>C2300</td>
<td>CORMAX2300</td>
<td>0.93</td>
<td>796</td>
<td>SSMC</td>
</tr>
</tbody>
</table>

\textsuperscript{a}C2300 was SmCo5, others were Nd2Fe14B. All magnets were magnetized perpendicular to the pressing direction. Vacuum schmelze: VAC; Sumitomo Special Metals: SSMC.

\textsuperscript{b}Manufacturers report values.

---

Fig. 4. (a) The magnetic field change of the different materials as a function of the accumulated electron dose. (b) The magnetic field distribution change of the magnet in the direction transverse to the electron beam.
environments other than 2 GeV electron beams) are the following (1):

1) SmCo magnets are in general more radiation resistant than NdFeB magnets regardless of the source of radiation (i.e. neutrons, photons or charged particles) The order of radiation resistance appears to be Sm$_2$Co$_{17}$, SmCo$_5$ and Nd$_2$Fe$_{14}$B
2) The higher the coercivity the higher the radiation resistance
3) Significant differences in terms of radiation resistance have been observed between magnets from different vendors that appear to be due to microstructural differences and impurities.
4) The mechanism of damage is still unknown though some models have been proposed such as in the case of proton damage (i.e., creation of local hot spots that could lead to temperature rises exceeding the Curie temperature of the magnet). In addition, it is believed that the superiority of SmCo with respect to radiation damage is due to its higher Curie temperature (that is 820°C or 780°C depending on grade) and its superior thermal properties. The Curie temperature for the N39SH NdFeB that was initially proposed for the LCLS is 365°C.
What to Do

- Research and Study everyone else’s experience
- Determine whether SmCo is significantly better than NdFeBo
- Define the commissioning plan
- Determine the trigger level to stop beam
- Develop a reliable detector to act as the trigger